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DESCRIPTION

VACUUM APPARATUS

Technical Field

[0001] This invention relates to a vacuum apparatus and, in particular, relates to a vacuum apparatus for use in the field of manufacturing semiconductor devices, flat panel display devices, or the like.

Background Art

[0002] vacuum apparatuss have been used in the semiconductor manufacturing field and many other industrial fields.

[0003] The vacuum apparatus generally comprises a vacuum container and vacuum pumps for keeping the inside of the vacuum container in a vacuum or depressurized state.

[0004] The vacuum apparatus is disposed in a clean room and is configured to perform predetermined processing while introducing and exhausting a predetermined process gas into and from the vacuum container.

[0005] A vacuum apparatus of this type having vacuum pumps of a plurality of stages for use in the manufacturing field of a semiconductor device manufacturing apparatus is disclosed, for example, in Patent Document 1.

[0006] In the conventional vacuum apparatus of this type, a high vacuum pump as a first vacuum pump is connected to a reaction chamber in order to bring the inside of the reaction chamber into a depressurized or vacuum state, and a booster pump as a second vacuum pump and a back pump as a third vacuum pump are respectively arranged at a subsequent stage of the high vacuum pump.

[0007] Generally, use is made, as the high vacuum pump, of a high vacuum pump that operates in a molecular flow region of ultimate pressure (10^{-7} Torr or less). Specifically, a turbomolecular pump or a thread groove pump is generally used as the high vacuum pump.

[0008] The turbomolecular pump and the thread groove pump each generally have a low allowable back pressure of 1 Torr or less (specifically 0.5 Torr or less) while the pumping speed is high even with a small size. Therefore, there is/are provided, at the subsequent stage of the high vacuum pump, an intermediate/low vacuum pump or intermediate/low vacuum pumps in one or two stages which each operate at a relatively low back pressure while the ultimate pressure is relatively low.

[0009] For example, in the case where vacuum pumps are provided in two stages at the subsequent stage of the high vacuum pump, a booster pump or the like is provided subsequent to the high vacuum pump as an intermediate vacuum pump and, further, a back pump (Roots-type back pump or the like) is provided subsequent to the booster pump as a low vacuum pump that operates at a relatively low back pressure while the ultimate pressure is low.

[0010] In many cases, a gas exhausted from the reaction chamber is discarded. However, particularly when a noble gas such as krypton or xenon is used for plasma excitation, or the like, the expensive noble gas is normally recovered. In this case, the discharge side of the back pump is connected to a compressor of a recovery apparatus. The compressor of the conventional recovery apparatus merely accumulates an input gas, increases its pressure, and discharges it.

[0011] As described above, in a vacuum apparatus for use in the manufacture of a semiconductor device manufacturing apparatus, use is generally made of two or three vacuum pumps in multistages with respect to one reaction chamber (vacuum container). These vacuum pumps often have mutually different

structures as described above, but are all driven by electric motors. Accordingly, in the vacuum apparatus of this type where the number of vacuum pumps used is large, the power consumption increases. Since the power consumption of the vacuum apparatus resultantly affects the manufacturing cost of the semiconductor device manufacturing apparatus, it is desired to reduce the power consumption.

[0012] Particularly, since the last-stage low vacuum pump (back pump) among the multistage vacuum pumps is required to have a large capacity, the power consumption thereof is also large. Therefore, it is effective and desirable to suppress the power consumption of the back pump for a reduction in power consumption of the entire vacuum apparatus and thus a reduction in manufacturing cost of the semiconductor device manufacturing apparatus.

[0013] Herein, the reasons of the large power consumption of the back pump are firstly that since its discharge side is the atmosphere (the atmospheric pressure is 760 Torr), the exhaust operation should always be carried out (even when the reaction chamber is not operated) in order to prevent back diffusion to the inlet side from the atmospheric side and secondly that although a depressurized gas enters from the inlet side, the gas does not go out into the atmosphere unless its pressure is increased to the atmospheric pressure or more.

[0014] Patent Document 1:

Japanese Unexamined Patent Application Publication (JP-A) No. 2002-39061

Disclosure of the Invention

Problem to be Solved by the Invention

[0015] Therefore, it is an object of this invention to provide a vacuum apparatus and a vacuum pump that can suppress the power consumption.

Means for Solving the Problem

[0016] According to this invention, there is obtained a vacuum apparatus characterized by comprising a vacuum container having a gas inlet and a gas outlet, a vacuum pump of at least one stage connected to the gas outlet of the vacuum container for depressurizing the inside of the vacuum container or maintaining the inside of the vacuum container in a depressurized state, and a compressor connected to a discharge port of the last-stage vacuum pump of the at least one-stage vacuum pump and having capability of depressurizing an input side of the compressor.

[0017] The number of vacuum pump stages is set to one stage or a plurality of stages depending on a gas amount introduced into the vacuum container or the capability of the vacuum pump.

[0018] In this invention, it is preferable that a gas recovery apparatus for recovering a gas discharged from the last-stage vacuum pump for re-use of said gas be provided and the compressor be a gas recovery compressor in the gas recovery apparatus.

[0019] Further, according to this invention, there is obtained a vacuum apparatus comprising a container to be depressurized having a gas inlet and a gas outlet, mechanical vacuum pumps of a plurality of stages connected to the container for depressurizing the inside of the container and maintaining the inside of the container in a depressurized state, and a gas recovery apparatus for recovering a gas discharged from the last-stage vacuum pump for re-use of said gas, the vacuum apparatus characterized by comprising a gas recovery compressor connected to a discharge port of the last-stage vacuum pump and having depressurization capability for assisting a depressurization operation of the last-stage vacuum pump and suppressing back diffusion from the discharge port.

[0020] When a supply amount of a gas introduced into the container to be

depressurized is smaller than a predetermined amount (in this case, the pumping speed of the gas recovery compressor relatively increases, thereby enabling evacuation to a predetermined back pressure or less of the preceding-stage vacuum pump), the last-stage vacuum pump is omitted, a gas discharged from the vacuum pump at the stage prior to the last stage is recovered and reused by the gas recovery apparatus, and the gas recovery compressor is connected to a discharge port of the vacuum pump at the stage prior to the last stage.

[0021] The vacuum pumps in the plurality of stages may comprise a first vacuum pump, a second vacuum pump connected at a subsequent stage of the first vacuum pump, and a third vacuum pump connected at a subsequent stage of the second vacuum pump and, in this case, it is preferable that the first vacuum pump be a turbomolecular pump or a thread groove pump, the second vacuum pump be a booster pump, and the third vacuum pump be a dry pump. When a supply amount of an introducing gas is smaller than a predetermined amount (in this case, the pumping speed of the gas recovery compressor relatively increases, thereby enabling evacuation to a predetermined back pressure or less of the preceding-stage vacuum pump), the third vacuum pump is omitted and the compressor having the depressurization capability is connected to the second vacuum pump.

[0022] It can also be said that the compressor additionally attached to the discharge port of the last-stage pump, particularly the discharge port exposed to the atmospheric side, has the function of a vacuum pump.

Effect of the Invention

[0023] In the vacuum apparatus according to this invention, since the gas recovery compressor having the function of a vacuum pump or having the depressurization capability is connected to the discharge port of the last-stage

vacuum pump, the compressor assists the depressurization operation of the last-stage vacuum pump (i.e. since the compressor having the depressurization capability reduces the pressure at the discharge port of the last-stage vacuum pump, the last-stage vacuum pump is not required to increase the pressure of the sucked gas to the atmospheric pressure or more) and suppresses back diffusion from the discharge port of the last-stage vacuum pump and, hence, it is possible to suppress the power consumption of the last-stage vacuum pump as compared with conventional and, as a result, it is possible to reduce the manufacturing cost of a semiconductor device manufacturing apparatus or the like.

Brief Description of the Drawings

[0024] [Fig. 1] is a schematic diagram showing a semiconductor manufacturing vacuum apparatus according to an embodiment of this invention.

[Fig. 2], (a) and (b) are sectional views showing a screw pump as a last-stage vacuum pump of the vacuum apparatus according to the embodiment of this invention.

[Fig. 3] is a diagram showing the relationship between the inlet pressure and the power consumption of the pump along with that of a comparative example for explaining the operation and effect of this invention.

Description of Symbols

[0025] 1, 2, 3 high vacuum pump

4a, 5a, 6a, 7a, 8a, 9a booster pump

4b, 5b, 6b, 7b, 8b, 9b back pump

4c, 5c, 6c, 7c, 8c, 9c compressor

10, 11, 12 reaction chamber

13, 14 load lock chamber

15 transfer chamber

25 male rotor

26 female rotor

27, 28 rotation shaft

31, 32 timing gear

33 water cooling jacket

42 main casing

43 end plate

46, 55 auxiliary casing

56 inlet port

57 discharge port

B gas recovery apparatus

Best Mode for Carrying Out the Invention

[0026] Hereinbelow, an embodiment of a vacuum apparatus of this invention will be described with reference to the drawings.

Embodiment 1

[0027] Referring to Fig. 1, this vacuum apparatus comprises a plurality of reaction chambers 10, 11, and 12, high vacuum pumps 1, 2, and 3 as first vacuum pumps one or a plurality of which are arranged for each of the reaction chambers 10, 11, and 12 in order to bring the inside thereof into a depressurized or vacuum state, and booster pumps 4a, 5a, and 6a as second vacuum pumps and back pumps 4b, 5b, and 6b as third vacuum pumps that are arranged at subsequent stages of the high vacuum pumps, respectively.

[0028] Further, valves 22, 23, and 24 are provided between the high vacuum pumps 1, 2, and 3 and the booster pumps 4a, 5a, and 6a, respectively.

[0029] There are further provided load lock chambers 13 and 14 for

transferring processing objects such as wafers to the reaction chambers 10, 11, and 12 and a transfer chamber 15 provided therein with a robot (transfer apparatus) that transfers the processing objects, brought into the load lock chamber 13, into the reaction chambers 10, 11, and 12 and transfers them from the reaction chambers 10, 11, and 12 into the load lock chamber 14.

[0030] A booster pump 8a, a back pump 8b, and a compressor 8c are connected to the load lock chamber 13, a booster pump 7a, a back pump 7b, and a compressor 7c are connected to the load lock chamber 14, and a booster pump 9a and a back pump 9b are connected to the transfer chamber 15, thereby being capable of bringing those chambers into depressurized or vacuum states, respectively.

[0031] Further, although not illustrated, the reaction chambers 10, 11, and 12 are each provided with a gas inlet and heating means such as a heater to thereby carry out predetermined processing such as film formation while introducing a predetermined gas under heating.

[0032] In the figure, symbols A1 denote pipes between the high vacuum pumps 1, 2, and 3 and the booster pumps 4a, 5a, and 6a, respectively, while symbols A2 denote pipes between the reaction chambers 10, 11, and 12 and the high vacuum pumps 1, 2, and 3, respectively. Further, in the figure, symbol R denotes a clean room.

[0033] In the state where this vacuum apparatus is on standby, the transfer chamber 15 and the reaction chambers 10, 11, and 12 are each held in a depressurized or vacuum state.

[0034] Then, a cassette with a plurality of processing objects such as wafers placed therein is brought into the load lock chamber 13 from the atmosphere outside the system and the load lock chamber 13 is evacuated.

[0035] Subsequently, a gate valve (not illustrated) between the load lock chamber 13 and the transfer chamber 15 is opened and the processing object

transfer robot uses its transfer arm to pick up one of the processing objects from the cassette and transfer it into the transfer chamber 15.

[0036] Thereafter, a gate valve (not illustrated) between the reaction chamber 10 and the transfer chamber 15 is opened and the processing object is placed on a stage in the reaction chamber 10 by the use of the transfer arm.

[0037] Then, after the predetermined processing such as film formation, the processed object is transferred into the other reaction chamber 11 or 12 or the load lock chamber 14 by the use of the transfer arm.

[0038] Then, after the processing, the processed object is finally transferred to the exterior from the load lock chamber 14.

[0039] In the system shown in Fig. 1, use is made, as the high vacuum pump, of a high vacuum pump that operates in a molecular flow region of ultimate pressure (10^{-7} Torr or less). Specifically, a turbomolecular pump or a thread groove pump is used as the high vacuum pump.

[0040] The turbomolecular pump and the thread groove pump each generally have a low allowable back pressure of 1 Torr or less (specifically 0.5 Torr or less) while the pumping speed is high even with a small size. Therefore, there is/are provided, at the subsequent stage of the high vacuum pump, an intermediate/low vacuum pump or intermediate/low vacuum pumps in one or two stages which each operate at a relatively low back pressure while the ultimate pressure is relatively low.

[0041] For example, in the case where vacuum pumps are provided in two stages at the subsequent stage of the high vacuum pump, a booster pump or the like is provided subsequent to the high vacuum pump as an intermediate vacuum pump and, further, a back pump (Roots-type back pump or the like) is provided subsequent to the booster pump as a low vacuum pump that operates at a relatively low back pressure while the ultimate pressure is low.

[0042] In this invention, the back pumps 4b, 5b, 6b, 7b, 8b, and 9b serving as

the vacuum pumps at the last stage in Fig. 1 are respectively provided with gas recovery apparatuses B incorporated with compressors 4c, 5c, and 6c each having a vacuum pump function that can assist the depressurization operation by the back pump or suppress back diffusion from a discharge port of the back pump and compressors 7c, 8c, and 9c each having the vacuum pump function.

[0043] In the embodiment 1 of this invention, the back pumps 4b, 5b, 6b, 7b, 8b, and 9b in Fig. 1 have screw pumps, respectively.

[0044] Referring to Fig. 2, (a) and (b), a male rotor 25 and a female rotor 26 of the screw pump are received in a main casing 42 and rotatably supported by bearings 35 and 36 attached to an end plate 43 sealing the main casing 42 on its one end side and bearings 37 and 38 attached to an auxiliary casing 46, respectively.

[0045] Timing gears 31 and 32 accommodated in the auxiliary casing 46 are mounted on rotation shafts 27 and 28 of the male and female rotors 25 and 26, respectively, and a gap between the male rotor 25 and the female rotor 26 is adjusted so that both rotors do not contact each other. Further, a motor M is attached to the rotation shaft of the male rotor 25 through a coupling or speed change gear. It is configured that the rotation of the motor M is transmitted to the male rotor 25 and rotates the female rotor 26 through the timing gears 31 and 32.

[0046] An auxiliary casing 55 provided with an inlet port 56 is attached to the main casing 42 on its one end side. Further, the end plate 43 of the main casing 42 is formed with a discharge port 57 for discharging a gas compressed by the male rotor 25 and the female rotor 26.

[0047] Since the main casing 42, the compressed gas, and so on rise in temperature due to the compression of the gas, a cooling jacket 33 is formed on the outside of the main casing 42. A coolant such as water is circulated in the cooling jacket 33 to thereby cool the main casing 42, the compressed gas, and

so on.

[0048] In the screw pump thus configured, when the male rotor 25 is driven by the motor M, the female rotor 26 is rotationally driven through the timing gears 31 and 32. Then, following the rotation of the male rotor 25 and the female rotor 26, a gas from the corresponding one of the upper-stage booster pumps 4a, 5a, 6a, 7a, 8a, and 9a (Fig. 1) is sucked through the inlet port 56 into a working chamber formed by the male rotor 25, the female rotor 26, and the main casing 42. The sucked gas is discharged through the discharge port 57 while being compressed following the rotation of the male rotor 25 and the female rotor 26.

[0049] Herein, this vacuum apparatus is provided with the gas recovery apparatuses B incorporated with the compressors 4c, 5c, and 6c and the compressors 7c, 8c, and 9c having the vacuum pump function and connected to the discharge ports 57 of the screw pumps 4b, 5b, 6b, 7b, 8b, and 9b for suppressing the back diffusion through the discharge ports 57 from the exterior near the atmospheric pressure to thereby reduce the power consumption.

[0050] As a result of this, the back diffusion through the back pumps 4b, 5b, 6b, 7b, 8b, and 9b is largely reduced, thereby enabling a large reduction in power consumption. The ultimate pressure of the compressor (4c, 5c, 6c, 7c, 8c, or 9c) having the vacuum pump function can be reduced to approximately 300 Torr.

[0051] Fig. 3 shows the results of examining the relationship between the pressure at the inlet port 56 of the screw pump and the power consumption of the screw pump when the screw pumps were used as the back pumps 4b, 5b, 6b, 7b, 8b, and 9b in the vacuum apparatus shown in Fig. 1. In this examination, the measurement was carried out in the case where the exhaust was performed with the compressors 4c, 5c, 6c, 7c, 8c, and 9c, having the vacuum pump function, connected to the discharge ports of the back pumps 4b,

5b, 6b, 7b, 8b, and 9b and in the case where no compressor having the vacuum pump function was connected to any of the back pumps 4b, 5b, 6b, 7b, 8b, and 9b.

[0052] As clear from Fig. 3, with respect to the screw pump having the compressor with the vacuum pump function, the power consumption is low overall regardless of the inlet pressure as compared with the screw pump having no compressor with the vacuum pump function. Particularly, when the inlet pressure is 10 Torr or less, the screw pump having the compressor with the vacuum pump function is reduced in power consumption by approximately 50% as compared with the screw pump having no compressor with the vacuum pump function.

[0053] In other words, in the case where the screw pumps are applied as the back pumps 4b, 5b, and 6b of the vacuum apparatus shown in Fig. 1, a higher effect is achieved when no gas is introduced into any of the reaction chambers 10, 11, and 12 (Fig. 1).

[0054] The number of stages of the vacuum pumps in the vacuum apparatus according to this invention is not limited to the multistage structure but may be two stages or one stage. That is, a vacuum pump (last-stage vacuum pump) to be connected with a compressor is not limited to a back pump in a multistage structure but may be a second-stage vacuum pump in a two-stage structure or a first-stage vacuum pump in a single-stage structure as long as the back pressure thereof is within a pressure range over which the effect of the compressor appears. Further, this vacuum pump may be one of various types of vacuum pumps such as the Roots type.

[0055] Description will next be given in detail of the fact that the last-stage back pump 4b can be omitted when the supply amount of the gas introduced into the reaction chamber 10 in Fig. 1 is smaller than a predetermined amount.

[0056] The predetermined amount of the gas supply in this case is determined

based on various conditions, particularly the process pressure, the performance (back pressure, pumping speed, etc.) of the booster pump 4a, and the performance (pressure, pumping speed, etc.) of the compressor 4c. For example, assuming that the process pressure is 5 Torr, the booster pump 4a has the performance with the back pressure being 200 Torr and the pumping speed being 2000 L/min, and the compressor 4c has the performance with the pressure being 200 Torr and the pumping speed being 50 L/min, since the performance of the booster pump 4a is not exhibited unless the back pressure of the booster pump 4a is set to 200 Torr or less, it is necessary that the pressure at a discharge port of the booster pump 4a be evacuated to 200 Torr or less by the compressor 4c. Since, in this event, an equation of "introducing gas amount × 760 Torr (atmospheric pressure) / pumping speed 50 L/min of the compressor 4c = 200 Torr (back pressure of the booster pump 4a)" is established, the maximum introducing gas amount is derived to be 13 L/min through calculation of this equation. When the reaction chamber 10 with this introducing gas amount of 13 L/min is evacuated by the booster pump 4a (back pressure 200 Torr, pumping speed 2000 L/min), the chamber pressure becomes "introducing gas amount 13 L/min × 760 Torr (atmospheric pressure) / pumping speed 2000 L/min of the booster pump 4a = 5 Torr" and, hence, the introducing gas amount of 13 L/min can be flown if the process pressure is 5 Torr or less. That is, under the foregoing conditions, when the supply amount of the gas introduced into the reaction chamber 10 is 13 L/min or less, the last-stage back pump 4b can be omitted and further the high vacuum pump 1 can also be omitted, wherein the reaction chamber 10 can be evacuated by the booster pump (second vacuum pump) 4a and the compressor 4c.

Industrial Applicability

[0057] In the foregoing embodiment, the description has been made of the

semiconductor device manufacturing vacuum apparatus. However, the use of the vacuum apparatus of this invention is not limited to a semiconductor device manufacturing apparatus but it can be used in every industrial field that requires depressurization.